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RESEARCH MEMORANDUM

A SAC ALERT CONCEPT FOR THE IMMEDIATE FUTURE

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Mr. Walter Nelson
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Dear Mr. Nelson:

This responds to your letter of February 10, 1995, which voluntarily forwarded the enclosed research memorandums, for security review. The research memorandums are cleared for open publication and identified as:

- 95-S-3173: *Resource Allocations and Future Weapon Systems*
- 95-S-3174: *An Arms Race*
- 95-S-3175: *The Impact of Military Power on the Cold War*
- 95-S-3176: *Command Support Systems: Introduction*
- 95-S-3177: *Soviet Strategy and the Initiation of War*
- 95-S-3178: *A SAC Alert Concept for the Immediate Future*
- 95-S-3180: *Berlin: Some Notes on a Developing Crisis*
- 95-S-3181: *Comments on C. M. Crain's D(L)-9596-PR, "Thoughts Relative to Advantages of 100 MT Class Bombs"*

Sincerely,

S. F. Reinke
Chief, Navy and Air Force Divisions
Directorate for Freedom of
Information and Security Review

Enclosure:
As stated

SUMMARY

The maintenance problem is one of the major bottlenecks which impede a high state of alert for SAC bomber forces. It has manifested itself in the small number of aircraft on short-notice alert and in the substantial time it has taken to bring the remaining aircraft to an alert status. In the past, this did not degrade SAC's deterrent strength to an unacceptable level, since the enemy's first-strike capabilities were so limited that a good many SAC bombers would have been able to take off even five or six hours after the enemy blow. In the future, however, the enemy's increasing missile force will mean that none of SAC can count on the luxury of hours of warning.

This paper makes two basic proposals for mastering this very dangerous situation: a maintenance policy intended to push aside some maintenance impediments to a high state of alert; and an alert policy which would help minimize the effects of the remaining maintenance impediments.

The basis of the new alert policy is to keep special weapons and fuel on all operationally-ready airplanes which are not actually flying, and thus put as many airplanes as possible onto alert status. Present SAC policies of scheduling alert aircraft by tail number well in advance of their two-week alert period can produce an estimated 9 alert planes per wing of B-52's dispersed to three squadron sites. Utilizing all aircraft which have completed maintenance could produce an average of about 14.4 alert planes per dispersed wing. If those aircraft were also put on alert which needed repairs but could still fly combat missions, 7.6 "secondary alert" planes could be added to the 14.4 "primary alert" for a total of 22 -- more than twice the present number of about 9.

The basic alteration proposed in maintenance policies is that SAC change from its one-shift-per-day, five-day-per-week maintenance activity to a round-the-clock, seven-day-per-week policy. With only minor increases in manning, this could increase the maximum number of planes in the present type of prescheduled alert from 9 to 11. Much more important, if combined with the suggested primary- and secondary-alert policies, it could increase the number of aircraft available for immediate combat missions from 22 to 27 -- three times the number available with no changes in alert or maintenance policies.

The suggested changes will increase costs and necessitate solution of problems in areas not treated in this study. These problems include necessary supervision, placing mess and other facilities on a 24-hour basis; additional special weapons, loading teams, loading equipment and security personnel to care for the increased number of loaded aircraft; and aircrews to be able to take advantage of a much larger number of alert aircraft. For any significant improvement in the alert posture, SAC must overcome difficulties such as these, regardless of whether the improvement is achieved by the methods discussed here or by other means. The magnitude of the difficulty will be proportional to the degree of improvement.

It appears that SAC can approximately triple its deterrent and retaliatory force at additional costs which would be small compared to the present total cost of operating the B-52 force, or compared to the value of the increase in effective aircraft. We therefore believe the suggested plan warrants serious consideration.

TABLE OF CONTENTS

SUMMARY	iii
Section	
I. SIZE OF ALERT FORCES	1
II. ROTATING ALERT: A NEW CONCEPT	3
Primary Alert	3
Secondary Alert	5
III. ROUND-THE-CLOCK MAINTENANCE	9
IV. COMBINING THE ALERT AND MAINTENANCE PROPOSALS	11
V. RECAPITULATION OF THE PROPOSALS AND RESULTS	15
VI. COSTS	17
VII. CONCLUSION	19
APPENDIX: THE MODEL AND THE DATA	21

I. SIZE OF ALERT FORCES

The strategic forces of the United States are now much more vulnerable to attack than in the recent past and will become increasingly vulnerable in the future. Three fairly distinct phases can be seen. Until recently, SAC was able to count on several hours' warning of an enemy strike; its effective retaliatory force could be gauged by the number of aircraft which could take off on a combat mission within this timespan. As recently as 1957, therefore, SAC could consider a test alert successful if the first fully-armed B-52 took off six hours after the alert was sounded.¹ In the future, if the enemy has a full missile capability, we may not be able to count on any tactical warning whatever; in that event, our defensive schemes must be so devised that a great portion of SAC will survive and go into combat after the enemy missile strike.

The present, however, is a period of transition. There is little doubt that the enemy has some missile capability and more surprise-bomber-attack capability than he had in the past. Even so, there is a good chance that our bomber forces will get some warning, although it should now be counted in minutes rather than hours. To meet this immediate threat, SAC now has some bombers which are fully fueled, loaded with weapons, need no further maintenance, and are ready to go on fifteen-minute notice. These alert planes have a high probability of being able to take off on combat missions before an enemy strike. As things now stand, however, only a small number of aircraft have this capability; consequently, most of the remaining planes in a wing, except for a few isolated and lucky instances on which we should

¹This was true, for example, of a practice alert at Loring Air Force Base in September 1957.

not count, must be presumed dead under this present alert posture.¹ At Fairchild Air Force Base, when the 92d Bomb Wing went on full alert because of the Lebanon crisis, it took four hours merely to load each B-52, and the first plane which had not been included in the six-aircraft alert force did not become combat-ready until six hours after the order was given.

The difficulty is that, so far, SAC has not been able to keep very many of our basic strategic bombers, the B-52's, on alert and simultaneously carry out its necessary flight training program. At the time of writing, 9 is the maximum number of B-52's that have been placed on alert, out of the 45 in a wing. There has been discussion of, and planning for, an alert force of 15 aircraft per B-52 wing, but it has not materialized so far. It is recognized, both in and out of SAC, that it will be extremely difficult to achieve. Data from the 92d and 93d Bomb Wings at Fairchild and Castle Air Force Bases, which were used in this study, indicate that under present maintenance and alert policies and with present manning, no more than 13 or so B-52's could be placed on alert by the wings if they keep up their present flying rates. When SAC executes its present plans for squadron dispersal of B-52's, the maximum alert-force per wing will probably decline again to 9 or 10. Augmented manning can be expected to help very little if it is kept on the present one-shift-per-day basis.

The purpose of this paper is to propose certain changes in SAC's alert and maintenance concepts which we believe could triple the number of bombers on alert per wing.

¹If there is "strategic warning", the situation is of course much better; but we probably should not count on it.

II. ROTATING ALERT: A NEW CONCEPT

PRIMARY ALERT

Under present SAC policy, aircraft are assigned to alert status by tail number well ahead of time. These planes have bombs and fuel aboard, have all outstanding maintenance accomplished, and are ready to take off within about fifteen minutes. The alert schedule is part of the monthly flying and periodic maintenance schedule, with planes remaining on alert for about two weeks.

At present, 9 is the maximum number of B-52's on alert in a 45-plane wing. With present training flying programs and policies this number might be raised to as high as 13, but when SAC executes its planned move of B-52's from wing bases to squadron bases of 15 aircraft each, the maximum conventional alert per three-squadron wing will again drop to about 9.¹ Augmented manning will help little, if at all, because present manning already suffices for the shifts which are overworked; the big bottlenecks are the unmanned night- and weekend-shifts.

In addition to its alert aircraft, however, each SAC wing has a substantial number of B-52's which are considered "operationally ready"; that is, they are in a fully-maintained state with no repair work remaining to be done.

¹This numerical estimate, as well as all subsequent estimates of alert capabilities under proposed programs, was made with the help of a simulation model which is broadly described in the Appendix. In addition to predicting future situations, the model has successfully and accurately simulated B-52 wing base capabilities and programs observed in the past. The model is used in conjunction with B-52 data from Castle and Fairchild Air Force Bases, also discussed in the Appendix. For purposes of this paper, the model and the data are combined to simulate, under different alert and maintenance structures, a ten-day period at each of the three bases of a dispersed B-52 wing. During this period we have assumed that there are 87 bomber sorties, the same number flown during a similar period at Castle Air Force Base. Although we did not test the effects of our proposals on tanker capabilities, we assumed that the wing would maintain its full complement of KC-135's during the period and fly 30 tanker sorties.

Unlike the alert aircraft, they do not have their bombs aboard and may not be fully fueled. Primarily because of the time necessary to load special weapons on bombers, they cannot be considered immediately ready for combat. Estimates of the average number of these aircraft in a presently constituted wing run as high as 20 in addition to the alert planes, depending on how we define a "fully maintained aircraft". No single one of these operationally-ready planes remains in this status for very long, since these are the craft which are dispatched on training missions soon after maintenance is completed. Their total number is constantly renewed by other bombers moving up to the status of "operationally ready" from that of "undergoing maintenance."

The first proposal of this paper is to utilize the operationally-ready aircraft as alert planes, substituting for the 9 pre-scheduled two-week-alert B-52's a much larger average number of short-time-alert aircraft. Under this concept, specific aircraft would not be scheduled for alert; instead, a minimum quantity of alert planes would be fixed. This minimum would be achieved by drawing as necessary on whatever operationally-ready planes are available. In addition, as many other operationally-ready planes as possible would also be placed on alert to achieve a possible maximum rather than a necessary minimum. A plane would be considered available for this new "primary" alert if it were completely operationally ready, with all outstanding maintenance work completed. It would be considered actually on alert if, in addition, its bombs, chaff, and a predetermined fuel load were aboard. (As indicated below under SECONDARY ALERT, the bombs, chaff, and fuel may be loaded well before all maintenance work is complete.) Assuming no airborne alert, the plane would go off alert just before a training mission when the bombs are off-loaded.

Without any other changes, and with maintenance manning the same as that presently available to the 93d Bomb Wing at Castle Air Force Base, our

analysis indicates that the proposed alert concept would produce an average of 5.4 additional alert planes, over and above the basic number of 9 on alert per dispersed three-squadron wing. This would produce a total of 14.4 alert aircraft per wing -- almost two-thirds more than presently attainable.¹

SECONDARY ALERT

The immediate combat capability of a dispersed wing is not limited, however, to the average of 14.4 primary-alert planes. These planes were defined above as those which have all maintenance work completed, as is the case with alert aircraft under the present SAC concept. B-52's are so designed, however, that with their numerous alternative systems and modes, and their numerous systems which are useful but not vital to mission success, they can take off on combat missions if necessary with certain kinds of malfunctions left uncorrected.² Data from the 93d Bomb Wing at Castle Air Force Base indicate that only about 10 per cent of the flight-line-maintenance manhours expended over a period of five weeks were devoted to the repair of malfunctions which were critical for combat missions. This does not mean, of course, that 90 per cent of the maintenance effort was wasted. Many of the so-called non-critical malfunctions would have degraded performance if not repaired, and the remainder would have degraded or prevented missions if neglected very long. Nonetheless, the large majority of B-52 malfunctions will not prevent a combat mission if it must be flown.

¹Fractional numbers of aircraft are used here and there throughout the paper, since they are averages of various possibilities.

²The same holds true for the B-47, although to a lesser extent since it is smaller and has less room for alternative modes. In varying degrees, it will also be true for future bombers. It is much less true for fighters, which are much more compact packages of equally complex equipment.

In the light of the above, it seems possible to augment the average primary-alert force of 14.4 aircraft with a secondary or emergency alert force. This emergency alert force would consist of aircraft on which only non-critical maintenance jobs are unfinished. They would be considered available for emergency alert if all critical maintenance were completed and if no maintenance, critical or non-critical, were in process. The second qualification is necessary since it is not certain that aircraft being worked on, even for minor matters, can be buttoned up fast enough to insure their availability on short notice. This would exclude all aircraft in periodic or post-flight maintenance docks, as well as those currently undergoing flight-line maintenance.

Under this concept, the weapons and fuel would be loaded on an airplane immediately after accomplishment of both critical maintenance and any sort of maintenance which, for reasons of hazard or access, would require weapons or fuel to be off the craft. The plane would be considered on emergency alert for all time periods from bomb-loading to final accomplishment of all maintenance, except for those times when it was actually being worked on. It would automatically move to primary alert as soon as all maintenance was accomplished.

Obviously one key to the situation here is the identification of those malfunctions which would prevent an emergency combat mission until repaired. The authors have worked out a tentative list of them, in cooperation with SAC personnel and RAND engineers. The basic criterion was to consider a malfunction critical only if it induced a strong probability of mission failure. Accordingly, it was decided that no malfunction on the following systems would forestall an emergency combat mission:

- (a) autopilot
- (b) in-flight refueling
- (c) camera
- (d) fire control

- (e) gunnery
- (f) electronic countermeasures (ECM)
- (g) auxiliary radar
- (h) radio
- (i) fabric and paint

In some of these systems, such as ECM and radio, serious malfunctions could hamper a plane's mission, but if it accompanies others with these systems operational, a successful mission should be possible.

In the following systems, a variety of non-critical malfunctions can also occur; but the following listed malfunctions could prevent the mission and are therefore critical:

- (j) Power plant -- Complete disabling of one engine. In practice this means some but not all of the malfunctions which would cause a peacetime engine change.
- (k) Electrical -- Fewer than two alternators in; or indications of an electrical fire.
- (l) Hydraulic -- In practice, the existence of alternate modes means that practically all of the packs and their standbys would have to be out to cripple the aircraft.
- (m) Instrument -- Fuel flow gauge, EGT and EPR must all be out.
- (n) Bomb-Nav -- The criteria on this are too extensive to list. They were worked out by RAND personnel with a knowledge of the K System, for use in our analysis.
- (o) Fuel -- Only major leaks and leaks in certain fittings with a high fire danger were considered incapacitating.
- (p) Pneumatic -- Only the cabin pressure regulator's being out would cripple a mission.
- (q) Flight controls -- Spoiler out; stabilizer out.

(r) Landing gear -- Badly cut tire; all brakes completely out; landing-gear steering out.

(s) Weapons release -- Because of precautions necessary to avoid dropping a weapon on friendly territory, a variety of weapons-release malfunctions could prevent a mission.

The above list is not by any means final. It merely outlines some specific criteria which could be published by SAC as an easily understood guide to personnel charged with deciding whether or not a specific aircraft is combat ready.

Under the above definitions and criteria for an aircraft available for emergency alert, the analysis indicated that an average of 7.6 additional B-52's could be kept on secondary alert, with no changes except for the on-and off-loading of weapons as suggested above. Added to the 14.4 on primary alert, this would bring the total up to an average of 22 airplanes available for immediate combat missions out of a wing of 45 dispersed to three squadron bases, or almost two-and-a-half times the estimated maximum possible under present SAC alert procedures.

III. ROUND-THE-CLOCK MAINTENANCE

All of the above numerical estimates of increased alert capabilities have been made on the assumption that SAC will continue its present maintenance policy of working one shift a day, five days a week. Regardless of whether the suggested alert concepts are adopted, a move by SAC to three-shift-per-day, seven-day-per-week maintenance and flying could be expected to increase alert capabilities.

Under the present one-shift policies, standard procedure is to fly a bomber on a training mission on one day and refrain from all but routine after-flight maintenance until the next. The reason for this is that, since bombers normally fly training missions of eight hours or longer, missions which start during the regular working day will not end on that day. Aircraft crews returning from these missions report to maintenance debriefing teams who help define and record malfunctions discovered in flight and then turn their records over to "night planners" who plan the next day's maintenance work. Under these conditions, no plane is likely to be ready for either alert or another flight until at least 24 hours after landing, and since after-flight maintenance ordinarily lasts more than one eight-hour shift, 48 hours is a more likely estimate. This is true even when enough maintenance personnel are available in a single shift to do all necessary work. Because of access and electrical-power problems, not all necessary repairs can be done at the same time; for example, even though an aircraft may need radio maintenance and there is an available radio mechanic to do it, he may not be able to because electricians who are also working on the plane must have the power turned off.

With a move to three-shift, seven-day maintenance, work could begin as soon as the debriefers notify the maintenance control and dispatch section of necessary maintenance. Work could continue on the aircraft until it was put back into commission and thereby made available for alert or for flying. The radioman mentioned above, for example, could be scheduled to arrive at the aircraft as soon as the electrician finished, day or night.¹

Under its present alert concepts, SAC could spread a wing's maintenance manpower among three squadron sites. This would degrade alert capability. However, a further spread over 21 shifts per week (without working any man more than a 5-day 40-hour week) would raise the wing's capability for the present type of alert from the 9 planes discussed above only to a maximum of 10 or 11, since personnel would then be spread so thin that some specialties would be unmanned on some shifts. Nevertheless, round-the-clock maintenance would open the way to large benefits from augmented manning, even with present alert policies. Of course, if the increase in wing manning were entirely concentrated on the one shift per day now worked, the only major result would be a bigger crowd of men sitting around the dispatch desk waiting for work. Both SAC maintenance records and observation of the maintenance procedure on a B-52 base show that maintenance work is seldom held up for lack of personnel during work-time. The major delays occur on the shifts when no men are available. If the additional manpower were utilized to provide one or more additional shifts, consequently, there would be a real payoff: up to 15 planes per dispersed wing could be kept on a conventional alert, depending on the precise size of the augmentation. Even a small augmentation, concentrated in those specialties which would otherwise have unmanned shifts, would help considerably.

¹ A test of this procedure on a two-shift-per-day, five-day-per-week basis was made by the 92nd Bomb Wing of Fairchild Air Force Base, and worked out very well.

IV. COMBINING THE ALERT AND MAINTENANCE PROPOSALS

By far the greatest benefit from changing to round-the-clock maintenance would derive from combining it with the alert policies suggested in Section II above. The value of the "rotating" alert suggested there is limited under present one-shift maintenance procedures, since repairs on an aircraft are usually put off till the day after a training mission. This means that a plane which cannot be made available for primary or secondary emergency alert during one day-shift would have to wait until the next. To get the full benefit from rotating alert, personnel should start repairing an aircraft as soon as possible after it lands, and be available at all times to complete work on it. The job would be easier and the day-to-day number of alert aircraft less erratic if some planes were flying and landing at all times of day and night, thus staggering the workload.

If the rotating primary and secondary alert proposals were combined with a round-the-clock maintenance schedule, maintenance on a particular aircraft would proceed as follows:

1. Upon landing, the aircrew would be met by a debriefing team, just as at present. The team, using sets of criteria compiled by SAC, would identify critical malfunctions (ones which would prevent a combat mission), and those which must be corrected before weapons and fuel are again loaded on the plane.

2. As soon as the necessary work is scheduled, maintenance crews would go to the aircraft and correct all critical malfunctions.

3. Any maintenance would be accomplished which required that either weapons or fuel be off the aircraft.

4. Weapons and fuel would be loaded.

5. Remaining maintenance would be accomplished. As many jobs as possible would be done simultaneously, within the limits of electrical power and space considerations, in order to leave the plane unbuttoned for as short a time as possible.

6. Just before the plane flew its next training mission, weapons would be off-loaded.

Scheduling priorities would be set up to give first call on available personnel to critical maintenance and maintenance requiring weapons or fuel downloading. Beyond this, scheduling could follow the present SAC priority system of giving preference to those aircraft scheduled to fly next. Under this proposal, aircraft not in periodic or postflight maintenance or major modification would be unavailable for alert until the critical maintenance was accomplished, would be unavailable while weapons and fuel were off, and would be unavailable during non-critical maintenance but not while awaiting it. They would be available for either primary or secondary alert at all other times.

Combining the 21-shift-per-week policy and the proposed alert policies without augmenting personnel above present wing manning would, however, degrade the number of aircraft on primary alert from 14.4 to 13.5. This is true because the spreading out the present number of maintenance personnel would slow down some of the work necessary to make a plane available for primary alert. While decreasing the primary alert capability by one, however, it would increase the secondary alert capability by about six, from 7.6 to 13.5, increasing the total number of planes available for combat missions to 27 from the 22 possible with five-shift-per-week maintenance.

This represents a threefold increase over the nine-aircraft capability of SAC's present alert and maintenance policies.

Under the proposed combination of alert and maintenance policies, augmenting the number of maintenance personnel would not do much to increase the total number of aircraft on either primary or secondary alert. Present manning is sufficient to correct critical malfunctions and thus keep virtually all aircraft available for either primary or secondary alert. Additional personnel could, however, shift a number of aircraft from the secondary alert category to primary alert. The 13.5 planes now listed in secondary alert are those which have comparatively minor ailments and not enough personnel to work on them. Usually this is because spreading present wing personnel, first among the squadron sites and then among 21 shifts, means that some maintenance specialties are unavailable on some shifts. If additional personnel were made available in these skills, the situation would improve considerably. The analysis indicates that the major skill categories involved are in the autopilot, auxiliary radar, instrument and weapons-release systems.

V. RECAPITULATION OF THE PROPOSALS AND THE RESULTS

Table 1 summarizes the effects on alert capabilities of the various proposals in this paper. The table indicates the possibilities under three-squadron wing dispersal with present wing-maintenance-manning. It shows that the major possible improvement comes from the simplest of the proposals — that weapons be loaded on every bomber that appears capable of carrying them to the target. With present manning, the change of maintenance from a part-time to a round-the-clock affair would not significantly increase a wing's ability to sustain the present SAC type of alert, although, as we have seen, increased manning would in this case make possible to keep as many as fifteen planes per wing on conventional alert. Combining round-the-clock maintenance with rotating alert, however, would increase the average number of aircraft available for combat missions to 27, three times the number attainable under present policies, and 60 per cent of the total strength of a wing. Increases in personnel in this situation might improve combat performance by moving aircraft from a secondary to a primary alert category, but little could be done to increase the total number of alert aircraft.

RM-2303
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-16-

Table 1

AVERAGE ALERT STATUS UNDER ALTERNATE POLICIES
(B-52 Wing Dispersed to 3 Sites)

Policies	Average Number of Aircraft			
	On Present Type of SAC Alert	On "Rotating" Primary Alert	On "Rotating" Secondary Alert	Total Alert
Present SAC Maintenance and Alert Policies	9.0	-	-	9.0
Present SAC Maintenance Policies with Proposed Alert Policies	-	14.4	7.6	22.0
Present SAC Alert Policies with Proposed Maintenance Policies	11.0	-	-	11.0
Proposed Maintenance and Alert Policies	-	13.5	13.5	27.0

VI. COSTS

Certain cost increases would, in all probability, stem from the suggestions outlined above. While they are not spelled out in dollars and cents here, we believe that they are essentially marginal and would be quite minor compared to the total cost to SAC of operating a B-52 wing, compared to any other equally effective method of increasing combat capabilities, and compared to the value of the aircraft added to our deterrent force.

One important cost associated with the rotating alert program per se (as compared to the three-shift maintenance proposal) would be for additional weapons-loading teams and extra equipment necessary for them. Since we are proposing one loading and one unloading per plane between every two training flights, present crews, who now carry out only five or ten such jobs a week, presumably could not handle the extra load. More sentries for the additional alert planes would probably also be required, although a review of present security methods might minimize the increase.

The move to three-shift maintenance would necessitate additional maintenance supervisory personnel, but the increase would not be proportional. Without any personnel retraining or cross-training, shops might be consolidated to the extent that, for example, one supervisor per shift would oversee the work of both hydraulic and pneumatic specialists, or one supervisor would handle Bomb-Nav, auxiliary-radar and fire-control personnel. The change to three shifts would also cause certain costs for additional personnel support. It would cost something, for example, to keep messes and other facilities open 24 hours a day.

If SAC decides that the pay-off in shifting aircraft from the emergency ready to the fully ready category warrants the personnel augmentation outlined in this paper, this, of course, would have an additional cost.

In addition, since aircraft are not to be scheduled onto alert in advance, there is the problem of insuring compatibility of mission assignment and aircraft configuration. With 27 alert aircraft, it should be possible to meet at least the minimum requirement of 15 primary mission assigned aircraft.¹

Finally, there is the question of additional aircrews, which will be a major problem. The proposed system provides up to 12 more combat-ready aircraft in the first hours of a war than is presently planned. SAC now plans to have enough aircrews available to man the 15-aircraft-per-wing, 15-minute-alert posture. It is beyond the scope of this paper to investigate aircrew problems. Certainly, however, the potential aircraft alert improvements which have been discussed above seem to warrant concerted effort to arrive at acceptable aircrew problem solutions.

¹It should be noted that with present maintenance and alert policies it is doubtful whether 15 alert aircraft will be available at all. Being sure of 15 aircraft seems desirable even if configurations are not entirely correct.

VII. CONCLUSION

The proposals discussed in this paper are all aimed at the single goal of heightening SAC's ability to strike back against an enemy attack in the critical time period when some warning may still be expected. While the numerical estimates of alert capabilities may not be accurate here to the final degree of precision, the magnitude of the improvements which the proposed policies put within our reach are so large that the benefits should not be ignored.

APPENDIX

THE MODEL AND THE DATA

The key factor in measuring the effects of base maintenance throughout the Air Force is that, although accurate long-range estimates can be made of the average number of maintenance jobs and average job-durations, it is impossible to predict what work will be required for any one aircraft or for any one day. By using averages, rather reliable predictions of requirements can be made for particular years or perhaps months, but for any shorter period of time the reliability of a prediction drops very low. As a result, accurate estimates of proper manning, or of the effects of varying policies, cannot be made by using long-run averages. Not only will individual days vary widely from the average, but this variation will feed back and affect some of the most important estimates.

To give an example of what is meant, if the man-hours of K-system maintenance demanded each day were equal or almost equal to average daily man-hour demands over a long period of time, just enough man-hours could be made available to cover the average demand, and an accurate estimate could be made of aircraft out of commission for K-system time by computing the number of aircraft hours each day the K-system was being worked on. In actuality, however, man-hour demands in any one day may diverge widely from average daily demands. If manning were just sufficient to cover the average demand, aircraft might be grounded because of the personnel shortage on those days when demands were much greater than average. In that event, total aircraft out-of-commission time would be the sum of the number of aircraft hours the defective system was being worked on and the hours it was not. The fact that on some days demands would be much less than average would

not help. The lighter workload on these days would not enable personnel to increase aircraft in-commission time to counterbalance the loss on the heavy-demand days. Any estimate of necessary manning or of the results of maintenance or alert policy and concept changes must take account of such factors. The fact that manning is large enough throughout the Air Force to take care of demands considerably greater than average indicates that these factors actually are included in calculations, either explicitly or implicitly.¹

Any methodology designed to measure the effects of Air Force maintenance and alert policies must explicitly take account of such random factors as those described above. The model used for simulating SAC-base maintenance and alert structures on the IBM 704 computer, in order to produce the numerical estimates published in this paper, did so by using a random sampling or "Monte Carlo" technique. The essence of this technique is that in simulating on the computer the flows of aircraft into and out of various maintenance and alert states, the movement from one status to another is determined by the draw of a random number. The data gathered are used to calculate distributions of real-world probabilities of various movements, and these distributions are then programmed into the computer. The draw of a particular random number determines the particular point in the distribution used to describe one particular movement. In the K-system example used above, the distribution would have the same mean and other statistical characteristics as the real-world data. The particular random number drawn would determine whether, in a particular case, the maintenance demands would be greater or less than the long-run average and by how much. Thus the system is simulated by using

¹For a much more detailed analysis of the results of random variations in base maintenance, see W. P. Sewell, Maintenance-Operations Interactions at Base Level (U), The RAND Corporation, Research Memorandum RM-1960, 1 August 1958 (Secret).

probability distributions to cover the variety of possible short-run real-world cases, rather than by using means to cover the long-run averages.

Of course, many factors in base maintenance are better described by single numbers than by distributions. In the above example, the number of K-system mechanics available on a base, although it may vary somewhat, is basically determined by the number assigned and by leave and duty policies. It is relatively constant and can be expressed as a constant.

Figure 1 illustrates the flow of bombers through maintenance in the simulation model, and indicates the spots where various distributions or various constant numbers are used. The model itself is a general-purpose one, used for problems other than the ones discussed in this paper; for simplicity, certain features, not used here are left out of the figure. For the same reason, it omits tanker-flow through maintenance, which is almost exactly the same as that of bombers.

The model functions basically from random draws which specify various malfunctions and initiate demands of aircraft upon maintenance personnel to correct them. Available numbers of personnel are programmed into the model. If a random draw initiates a demand for personnel who are available, the airplane enters an "undergoing maintenance" state. If a series of previous draws have temporarily exhausted the number of available personnel in a specialty, the aircraft awaits maintenance of this particular type until mechanics are released from other jobs. Meanwhile, depending on whether personnel are needed to repair critical or non-critical malfunctions, the plane may or may not be available for secondary alert.

To describe the maintenance flow verbally:

1. Aircraft attempt to fly, according to a pre-planned flying program. The number that ground-abort is determined by a random draw from a pre-determined probability distribution.
2. Of those that succeed in taking off, some go into scheduled postflight or periodic maintenance upon landing, depending on the number of flying hours cumulated by the wing and the number required to generate a scheduled inspection. Those that do not go into scheduled maintenance join the ground-aborts in demanding unscheduled afterflight maintenance.
3. For the aircraft entering scheduled maintenance, it must be determined whether docks are available, since the total number of docks is pre-programmed. If they are, the craft enter the docks; if not, they must wait until a dock becomes available.
4. For each airplane demanding unscheduled afterflight maintenance, random draws determine what specialists are needed, whether the malfunctions are critical ones that can prevent a combat mission, and how long each type of personnel will be needed.
5. The same determinations are made for aircraft undergoing scheduled postflight or periodic maintenance, except that it is assumed that once a plane enters the docks it is unavailable for combat missions until the scheduled maintenance is complete, whether repairs to be made are critical or non-critical.
6. Available personnel are parcelled out to aircraft demanding maintenance. The pattern and sequence in which these mechanics work on each plane is determined by the previously determined demands for personnel, by the pre-programmed numbers of personnel available, and by pre-programmed rules which dictate how many specialties can work on a plane at the same time

and what specialties must wait because of electrical power and similar considerations. Planes actually being worked on at any time are listed either as undergoing scheduled postflight or periodic maintenance or unscheduled afterflight maintenance. Planes not being worked because personnel are unavailable are listed either as awaiting maintenance for a critical malfunction or for a non-critical malfunction. Planes in the latter group are available for secondary alert.

7. After all maintenance is complete, an aircraft is serviced and armed. This work takes a fixed length of time which is pre-programmed into the model. For convenience in simulation, all servicing, arming and weapons-loading is lumped together at this stage, although in present practice and in our suggested maintenance policies they are done at various times during the maintenance and alert periods. This does not affect our results as to numbers of aircraft available for alert.

8. After servicing, planes are available for primary alert. They remain so until they again attempt to fly, completing the circular flow.

Within this context, we can list the data inputs necessary to run the simulation model and describe the sources from which we obtain them:

1. Number of men available in each maintenance specialty. The number used here was the average number actually available to the flight line and docks day in and day out. The numbers were obtained directly from Maintenance Control of the 93d Bomb Wing at Castle AFB.
2. Flying program. This was taken from the 93d Bomb Wing Flying Schedule as amended by ground aborts, late takeoffs and cancellations.
3. Length of flight. The number used was eight hours for both bombers and tankers, roughly the average at a number of wings.
4. Ground-abort rate. The abort rate calculated from the 93d Bomb Wing Flying Schedule was about 3 per cent.

5. Number of flying hours to generate scheduled maintenance. The numbers used were 50 hours to generate a postflight inspection and 300 for a periodic, a new SAC policy now being phased in.
6. Number and length of demands on maintenance personnel. These were calculated by specialist type from specialist dispatches (SAC Form 526) from a five-week period at Castle AFB and a one-week period at Fairchild AFB. Since these forms for the most part do not cover work by non-specialist personnel in either the flight-line or docks, separate estimates were made of these.
7. Classification of malfunctions as to criticality. Each of the specialist dispatches in the sample described above was classified according to the set of criteria set forth in Section II.
8. Maximum number of specialist types working on an aircraft at one time, and sets of specialist types who could not work at the same time. The specialist dispatches were arranged chronologically by aircraft and statistical techniques, including analysis of variance, were applied to the observations of numbers and types of personnel who did work simultaneously.
9. Length of time for servicing, arming, etc. Servicing and arming times were estimated by observation and discussion at Castle and Fairchild. Special-weapon-loading time, which is crucial to our proposals, was estimated from two weeks of specialist dispatches at Fairchild, during one of which special weapons were being loaded for an emergency alert.

Using the above inputs, the simulation model gives answers on the number of aircraft in each of six states:

1. Operationally ready (available for primary alert).
2. Awaiting repair of a non-critical malfunction (available for secondary alert).
3. Flying training missions.
4. Undergoing scheduled maintenance (including servicing and arming).
5. Undergoing unscheduled afterflight maintenance.
6. Out of commission awaiting repair of a critical malfunction.

These numbers are reported both for the average of a simulated ten-day period and for each half-hour of this period. In order to give statistical meaning to the results, a number of simulation runs are made through the computer for each situation. The computer reports the mean values of the

states of aircraft for the entire period and the subperiod, and the standard deviation of these means. From these numerical outputs, particularly from the numbers of aircraft reported available for either primary or secondary alert, estimates are made each time of the number which actually could be on primary or secondary alert. Figure 2 gives an example of the result, showing the number of aircraft on primary and secondary alert for a ten-day period, under the assumption that SAC has adopted both the suggested policies concerning primary and secondary alert, and the policies concerning round-the-clock maintenance. It is easy to see that the system is quite sensitive to the fact that no personnel are available for work on night-shifts and weekends.

Similar calculations were made for each of the postures outlined in this paper, although it was not necessary to chart them in order to judge the results.

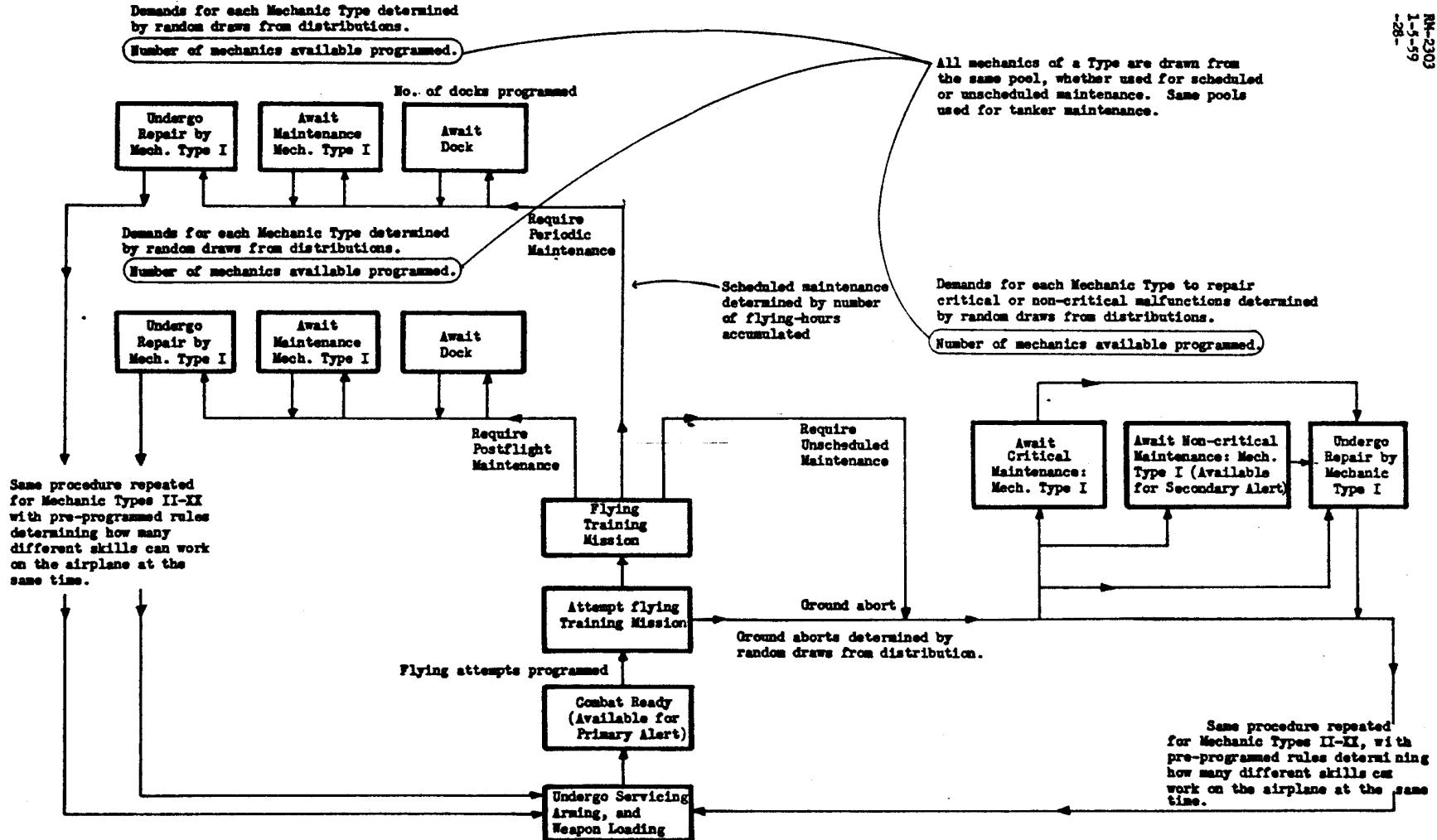


Fig. 1 — Flow of Bombers Through Maintenance in Simulation Model

Fig. 2—A model simulation of SAC wing alert capability
Ten-day period under proposed policies

